REMARKS

The specification has been amended to correct typographical and other minor errors of a formal nature. No new matter has been added.

Claims 2, 4, and 31 have been canceled. Claim 1 has been amended to incorporate the limitations of claims 2 and 4. Claim 21 has been amended to incorporate the limitations of claim 31. Claims 3, 5, and 14 have been amended to correct minor formal errors.

The examiner has acknowledged that claims 4, 6, 9, 10, 17, 22, 26, 28, 29 and 31 are directed to allowable subject matter. The limitations of allowable claim 4 (and intervening claim 2) have been incorporated into independent claim 1. Accordingly, claim 1 and all claims depending from claim 1 are now allowable. Similarly, the limitations of allowable claim 31 have been incorporated into independent claim 21. Accordingly, claim 21 and all claims depending from claim 21 are now allowable as well. Thus, all claims in the present application are amended to be allowable.

Attached hereto is a marked-up version of the changes made to the specification and claims by the current amendment. The attached page is captioned "**Version with markings to show changes made**."

Applicant respectfully requests that a timely Notice of Allowance be issued in this case.

Respectfully submitted,

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VERSION WITH MARKINGS TO SHOW CHANGES MADE

In the specification:

Paragraph beginning at line 19 of page 5 has been amended as follows:

The last two patents certainly go far in the direction of adaptively changing multiple antenna systems to optimize performance with varying channel conditions. However, further improvements are desirable. In particular, it would be desirable to develop a system where both the transmit unit and receive unit take full advantage of multiple antennas to not only adaptively change the modulation and/or coding but also use **a** suitable diversity scheme, **and** spatial multiplexing order all at the same time. These adaptive changes would help to ~~preserve~~ **ensure that** the communication parameters of the channel **remain** maximized while the channel varies. Furthermore, it would be an advance in the art to develop a communications system which could take advantage of multiple antennas at the transmit and receive unit to adapt to changing channel conditions and maximize any of a number of desirable communication parameters such as data capacity, signal-to-noise ratio and throughput. This would permit the system to continuously adapt to the type of data being transmitted via the channel.

Paragraph beginning at line 10 of page 6 has been amended as follows:

Accordingly, it is a primary object of the present invention to provide a method to maximize a communication parameter in a channel between a wireless transmit **unit** and receive unit, both using multiple antennas. Specifically, the method should permit **the system** to continuously optimize data capacity, signal-to-noise ratio, signal quality, throughput and other desirable parameters while the channel varies.

Paragraph beginning at line 18 of page 6 has been amended as follows:

It is a further object of the invention to provide a method which takes full advantage of multiple antennas at the transmit **unit** and receive unit to optimize a communication parameter of the channel using a quality parameter derived from the received signals.

Paragraph beginning at line 24 of page 6 has been amended as follows:

Yet another object of the invention is to provide a method as indicated above in any wireless communication system using any combination of multiple access techniques such as TDMA, FDMA, CDMA, **and** OFDMA.

Paragraph beginning at line 27 of page 7 has been amended as follows:

In a preferred embodiment, each of the spatial-multiplexed streams SM_i is processed by a coding unit to produce coded streams CS_h, where h=1...k'. The quality parameter is utilized in the transmitter to adjust the coding, e.g., by changing k', used by the coding

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unit. The coding unit can be a space-time coder, a space-frequency coder, ~~and~~ an adaptive modulation rate coder or other suitable coding device. The space-time and space-frequency coders can use different coding and modulation rates.

Paragraph beginning at line 1 of page 11 has been amended as follows:

The communication system can employ any one or more of the available multiple access techniques such as TDMA, FDMA, CDMA, OFDMA. This can be done in a wireless system, e.g., a cellular communication system.

Paragraph beginning at line 1 of page 13 has been amended as follows:

The time variation of channels **22A**, **22B** causes transmitted TS signals to experience fluctuating levels of attenuation, interference, multi-path fading and other deleterious effects. Therefore, communication parameters of channels **22A**, **22B** such as data capacity, signal quality or throughput undergo temporal changes. Thus, channels **22A**, **22B** can not at all times support efficient propagation of high data rate signals RS or signals which are not formatted with a robust coding algorithm. Antenna array **16** at BTS **12** can be used for spatial multiplexing, transmit diversity, beamforming to reduce interference, increase array gain and achieve other advantageous effects. Antenna arrays **20** at receive units **14** can be used for spatial multiplexing, interference canceling, receive diversity, increased array gain and other advantageous ~~effect~~ effects. All of these methods improve the capacity of channels **22A**, **22B**. The method of the invention finds an optimum combination of these techniques chosen adaptively with changing conditions of channels **22A**, **22B**. In other words, the method of the invention implements an adaptive and optimal selection of order of spatial multiplexing, order of diversity as well as rate of coding and bit-loading over transmit antenna array **16** to antenna array **20**.

Paragraph beginning at line 19 of page 14 has been amended as follows:

The details of a preferred embodiment of a transmit unit **50** for practicing the method of the invention are shown in Fig. 3. Data **52** to be transmitted is delivered to a data processing block **54**, where it first passes through an interleaver and pre-coder **56**. Interleaver and pre-coder **56** interleaves and pre-codes the stream of data **52**, as is known in the art and sends the interleaved and pre-coded stream to serial to parallel converter **58**. Converter **58**, produces from the single data stream a number k of spatial-multiplexed streams SM_i, where i=1...k and k is a variable, i.e., the number of streams SM_i is variable, subject to the condition that $1 \leq k \leq N$ and also $k \leq M$. In other words, the maximum number k of streams SM_i is limited by the ~~lower~~ smaller of the number M of transmit antennas $TA_1, TA_2, ..., TA_M$ and the number N of receive antennas $RA_1, RA_2, ..., RA_N$ (see Fig. 4).

Paragraph beginning at line 19 of page 15 has been amended as follows:

Each of the k streams SM_i ~~pass~~ passes through a corresponding Space-Time Coder **65** (S-T Coder) of an S-T Coding Unit **66**. Each S-T Coder produces k' coded streams CS_h, where h=1...k'. The number k' is at least 1 and at most M, depending on the number of

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streams SM_i selected by adaptive controller **60**. In fact, adaptive controller **60** is also connected to S-T Coding unit **66** to also control the number k'.

Paragraph beginning at line 17 of page 17 has been amended as follows:

For example, if the quality parameter which is fed back is SINR and the aim is to improve the throughput, then database **68** will contain the performance curves (BER versus SINR) for ~~**difference**~~ **different** S-T codes for all possible transmit/receive configurations in terms of number M of transmit antennas TA_1, TA_2, ..., TA_M and number N of receive antennas RA_1, RA_2, ..., RA_N. Fig. 8 shows the performance of three typical S-T codes. As can be seen, to achieve a BER of value q, which is suitable for the application (e.g., voice data transmission), ~~**and**~~ **when** the prevailing average SINR has to have a value p or less, only S-T codes 1 and 2 are suitable. S-T code 3 is not suitable because at SINR value p its BER is too high. Now, when the communication parameter to be maximized is the throughput, an additional choice is **to** be made between S-T code 1 and S-T code 2, and the one maximizing throughput is selected. A person of average skill in the art will see that this process or a similar process can be employed to maximize any of the communication parameters. In addition, preferably, database **68** contains the necessary performance curves to select the proper S-T codes, values of k and G(z) matrix sets to use. However, empirically collected data may also be used.

Paragraph beginning at line 6 of page 19 has been amended as follows:

Preferably, database **68** is also connected to unit **72** and contains stored parameters of suitable matrix sets G(z) for any given channel conditions or the matrix sets G(z) themselves. In the latter case adaptive controller **60**, which is also connected to database **68**, instructs database **68** to download the appropriate matrix set G(z) into transmit processing unit **72** as the channel conditions change. The choice of matrix set G(z) is made to facilitate the separability of the k spatial-multiplexed streams SM_i at the receiver. Matrix set G(z) can incorporate diversity techniques such as delay/switched diversity or any other combining techniques known in the art. For example, when no channel information is available at transmit unit **50**, e.g., at system initialization or at any other time, then matrix set G(z) (which consists of k MxM matrices) is made up of k matrices of rank ~~**MXk**~~ **M*k** such that the subspaces spanned by these matrices are mutually orthogonal to ensure separability of k streams at receive unit **80**. The task of finding such matrices can be performed by a person of average skill in the art. During operation, as the quality parameter changes, other sets of matrices G(z) can be also used.

Paragraph beginning at line 1 of page 21 has been amended as follows:

Matrix channel estimator **84** estimates the channel coefficients using known training patterns, e.g., the training patterns provided by training unit **70** in accordance with known techniques. In the present case, the output of estimator **84** is $\hat{A}(z)$:

$$\cancel{A(z)}\ \underline{\hat{A}(z)} = G(z)H(z),$$

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where G(z) is the matrix applied by transmit processing block **72**, and H(z) is the matrix of pure channel coefficients. G(z) is a set of MxM matrices while H(z) is an MxN matrix. The resulting matrix $\hat{A}(z)$ is an MxN matrix and represents channel estimates for received signals RS_1, RS_2, ..., RS_N after digitization. The channel estimates supplied to receive processing block **86** by estimator **84** are used by the latter to recover the k spatial-multiplexed streams SM_i. In fact, any of the well-known receive processing techniques such as zero-forcing (ZF), MMSE, LS, ML etc. can be used for processing received signals RS_1, RS_2, ..., RS_N.

Paragraph beginning at line 1 of page 21 has been amended as follows:

Thus, the choice of S-T codes for ~~**a separable k of**~~ **k separable** spatial-multiplexed streams SM_i can be based on the LCR and LC duration at a given threshold level and a maximum acceptable error rate. Average SINR can also give similar kind of information. This error information is used directly by unit **90** as the quality parameter or is used to derive the quality parameter. The other signal criteria can be used in a similar fashion to be employed by unit **90** directly as the quality parameter or to derive a quality parameter.

Paragraph beginning at line 11 of page 21 has been amended as follows:

Alternatively, and preferably in addition to unit **90** a signal statistics of output streams unit **94** is used to analyze reconstructed streams ~~**SMi**~~ SM_i obtained from S-T Decoding Unit **88**. Once again, unit **94** can perform the same statistical computations of reconstructed streams SM_i to obtain signal statistics including signal-to-interference noise ratio (SINR), signal-to-noise ratio (SNR), power level, level crossing rate (LCR), level crossing duration and reception threshold or other signal parameters. Meanwhile, reconstructed streams SM_i are converted to a serial stream by parallel to serial converter **96**. Then, they are de-interleaved and decoded by de-interleaver and decoder **98** to recover data **52'** (the prime indicates that the recovered data may differ from original data **52** due to transmission errors) originally transmitted from transmit unit **50**.

Paragraph beginning at line 1 of page 24 has been amended as follows:

During regular operation, transmit unit **50** selects G(z), k, k' and S-T codes at system initialization. These parameters are then updated as the channel changes. Transmit unit **50** sends control information **102** (see Fig. ~~5~~ 5A), including the S-T codes used, the value k, the matrix set G(z) being applied by transmit processing unit **72** etc. regularly to receive unit **80**. Alternatively, this information may be transmitted only once during initialization of a communication session and then updated as required (e.g., only when one of these pieces of information changes).

In the claims:

Claims 1, 3, 5, 14, 21 have been amended as follows:

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1. (**amended**) A method of maximizing a communication parameter of a channel between a transmit unit having a number M of transmit antennas and a receive unit having a number N of receive antennas, said method comprising the following steps:
   a) processing said data to produce parallel spatial-multiplexed streams SM_i, where i=1...k;
   b) mapping said spatial-multiplexed streams SM_i to transmit signals TS_p, where p=1...M, for transmission from said M transmit antennas to said receiver via said channel**, wherein the mapping comprises processing each of said spatial-multiplexed streams SM_i by a coding unit to produce coded streams CS_h, where h=1...k'**;
   c) receiving receive signals RS_j, where j=1...N by said N receive antennas;
   d) assessing a quality parameter of said receive signals RS_j; ~~and~~
   e) using said quality parameter to adjust k to maximize said communication parameter of said channel~~.~~ **; and**
   f) using said quality parameter in said transmit unit to adjust k'.

3. (**amended**) The method of claim ~~2~~ **1**, wherein said quality parameter is utilized in said ~~transmitter~~ **transmit unit** to adjust the coding of said coding unit.

5. (**amended**) The method of claim ~~2~~ **1**, wherein said coding unit is selected from the group consisting of space-time coders, space-frequency coders, adaptive modulation rate coders.

14. (**amended**) The method of claim 1, wherein said quality parameter is fed back to said ~~transmitter~~ **transmit unit**.

21. (**amended**) A communication system with an adaptively maximized communication parameter of a channel in which data is transmitted between a transmit unit having a number M of transmit antennas and a receive unit having a number N of receive antennas, said transmit unit comprising:
   a) processing means for processing said data to produce parallel spatial-multiplexed streams SM_i, where i=1...k;
   b) antenna mapping means for converting said spatial-multiplexed streams SM_i to transmit signals TS_p, where p=1...M, and transmitting said transmit signals TS_p from said M transmit antennas via said channel;

   said receive unit receiving receive signals RS_j, where j=1...N, and said communication system comprising:
   a) means for assessing a quality parameter of said receive signals RS_j; ~~and~~
   b) means for adjusting k based on said quality parameter to maximize said communication parameter of said channel~~.~~ **; and**
   c) an adaptive controller in communication with said processing means and said antenna mapping means, said adaptive controller adjusting said processing means and said antenna mapping means based on said quality parameter.

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